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Impacts of combined overfishing and oil spills on the plankton trophodynamics of the West Florida shelf over the last half century of 1965–2011: A two-dimensional simulation analysis of biotic state transitions, from a zooplankton- to a bacterioplankton-modulated ecosystem.

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ABSTRACT

Over 50 years of multiple anthropogenic perturbations, Florida zooplankton stocks of the northeastern Gulf of Mexico declined ten-fold, with increments of mainly dominant toxic dinoflagellate harmful algal blooms (HABs), rather than diatoms, and a shift in loci of nutrient remineralization and oxygen depletion by bacterioplankton, from the sea floor to near surface waters. Yet, lytic bacterial biomass and associated ammonification only increased at most five-fold over the same time period, with consequently little indication of new, expanded "*dead zones*" of diatom-induced hypoxia. After bacterial lysis of intact cells of these increased HABs, the remaining residues of zooplankton biomass decrements evidently instead exited the water column as malign aerosolized HAB asthma triggers, correlated by co-traveling mercury aerosols, within wind-borne sea sprays. To unravel the causal mechanisms of these inferred decadal food web transitions, a 36-state variable plankton model of algal, bacterial, protozoan, and copepod component communities replicated daily time series of each plankton group's representatives on the West Florida shelf (WFS) during 1965–2011. At the lower phytoplankton trophic levels, 52% of the ungrazed HAB increments, between 1965–1967 and 2001–2002 before recent oil spills, remained in the water column to kill fishes and fuel bacterioplankton. But, another 48% of the WFS primary production then left the ocean's surface as a harbinger of increased public health hazards during continuing sea spray exports of salts, HAB toxins, and Hg poisons. Following the *Deepwater Horizon* petroleum releases in 2010, little additional change of element partition among the altered importance of WFS food web components of the trophic pyramid then pertained between 2001–2002 and 2010–2011, despite when anomalous upwelled nutrient supplies instead favored retrograde benign, oil-tolerant diatoms over the HABs during 2010. Indeed, by 2011 HABs were back, with biomass accumulations equivalent to those found in 2001.

1. Introduction

Reoccupation in August 2010 of a NEGOM cross-shelf section off Panama City, Florida, sampled (Jochens and Nowlin, 2000) earlier during August 2000 (Fig. 1), may have provided a partial answer to what was the cause of anomalous phytoplankton accumulations there by August 2010 of as much as $\sim$5.0 ug chl l^{-1} above prior background levels during 2002–2009 (Hu et al., 2011), in this part of the WFS. Based on student *t*-test criteria, there were no significant differences in the phosphate contents of the water column there during August 2000 and 2010 (Fig. 2a). Except for significant depletion of nitrate within the aphotic zone of 500–1000 m depths, due to bioremediation of the *Deepwater Horizon* [*DWH*] fossil carbon substrates by aerobic denitrifying bacterioplankton (Fig. 2b), there was no difference in the realized interdecadal stocks of this other "new" nitrogen nutrient within the euphotic zone during August 2000 and 2010. Thus, any decadal changes of bottom-up controls of at least P- and N-limitation were unlikely causes of phytoplankton population increments found after the *DWH* oil spills.

Moreover, dinoflagellate *Pyrocystis lunula* bioassays of possible deleterious phytoplankton responses to oil contaminants and trace metal poisons (Okamoto et al., 1999; Heimann et al., 2002; Craig et al., 2003; Ozhan et al., 2014) then found there that any inhibitory impacts within the euphotic zone at a depth of 2 m were

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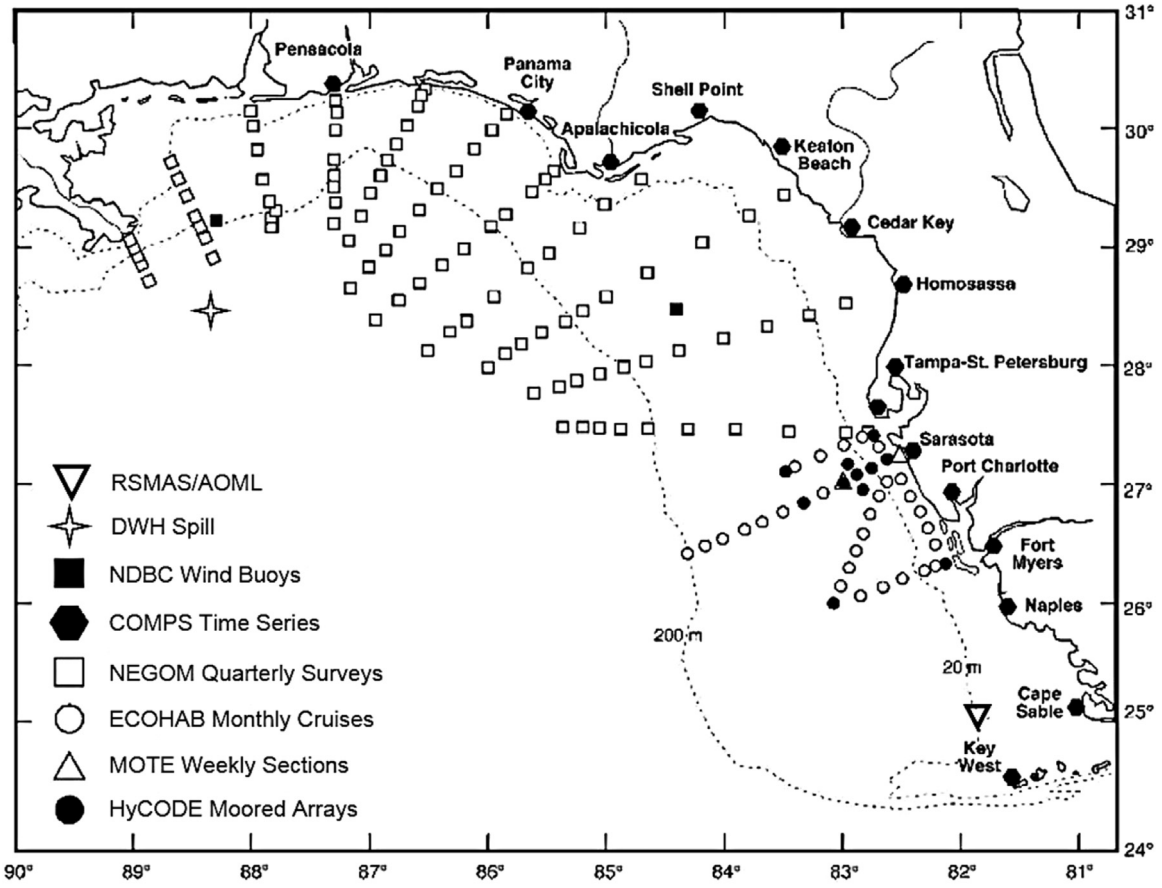

Fig. 1. Locations of decadal validation data of a 2-D numerical model along the cross-shelf section off Sarasota, Florida during 1965–2011, in relation to both prior ship-board observations obtained during: 1965–1967 [HOURGLASS stations over the same ECOHAB sampling grid]; 1998 [Mote sections]; 1998–2000 [NEGOM surveys]; 1998–2001 [ECOHAB cruises]; 1999-2000 [RSMAS/AOML], and the *Deepwater Horizon* (DWH) oil spill in 2010. Additional data were obtained during repeated C-IMAGE samplings during 2010–2011 near the Panama City cross-shelf survey in 2000.

only ~6.2% of potential growth during August 2010 at station DSH08 on the 1050-m isobath (Paul et al., 2013). Yet, significant decadal increases of both ammonium (Fig. 2c) and the bulk DON within the euphotic zone at station DSH08 during August 2010, as

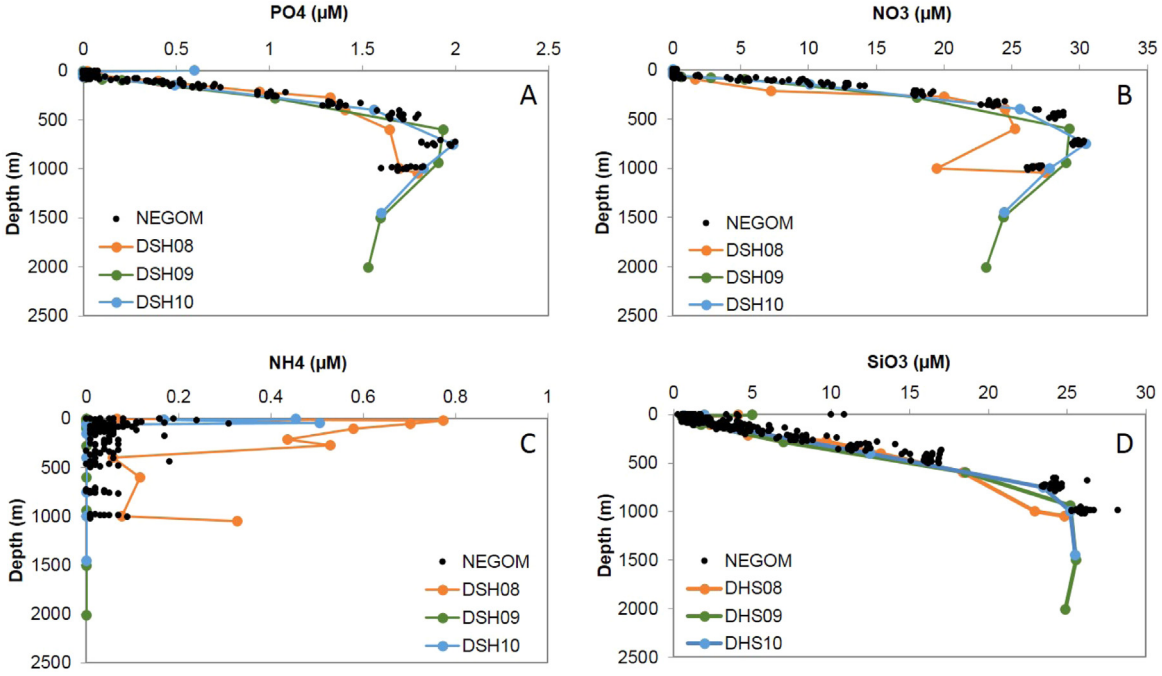

Fig. 2. Nutrient depth profiles of (A) phosphate, (B) nitrate, (C) ammonium, and (D) silicate at the shelf-break off Panama City, Florida, during NEGOM observations in August 2000, compared to those of more recent C-IMAGE stations DSH08, DSH09, and DSH10, occupied in the same WFS region during August 2010.